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Designing of Zeroth Order Antenna with Extended Bandwidth

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***Abstract*- This paper represents the designs and analysis of epsilon negative zeroth order resonant antenna. In this paper, design with vias and without vias are implemented and analysed to extend the bandwidth of proposed ZOR antenna which can be used for wireless applications like WLAN, WiMAX, Bluetooth etc. ZOR phenomena is used to reduce the physical size of proposed antenna (0.27λ x 0.53 x 0.017 λ) .**

***Keywords:* zeroth order resonanace(ZOR), extended bandwidth, epsilon negative transmission line (ENG-TL), microstrip.**

I. INTRODUCTION

Nowadays, microstrip patch antennas are widely used and its study has made great progress in recent years It has a wide number of applications like GPS, Bluetooth, missile systems, military purpose, WiMAX, WLAN, WiFi etc. due to its less complexity, less sensitivity, low volume, small size, light weight, affordable cost and easy implementation. And we are designing for wireless applications like WiMAX, Bluetooth, 3G, 4G, WLAN.

Metamaterials are those materials whose properties are defined from their internal structure rather than the matter of which it is composed of. It allow us to manipulate the wave propagation by changing its internal structure in different ways, either mechanically or electrically. They exhibits some unique properties like antiparallel phase and group velocities, and a zero propagation constant [2],[4],[5].

The zeroth order resonant antenna are based on CRLH transmission lines or epsilon negative transmission lines. Since the resonant frequency is independent of antenna size, we have an advantage of size reduction of ZOR antenna. But ZOR antennas suffer narrow bandwidth and low radiation efficiency which is bane for its wide applications. However, bandwidth depends on shunt inductance and capacitance and hence on manipulating these shunt elements bandwidth can be improved. As a result we get the better bandwidth for our wireless applications like WiMAX, Bluetooth, 3G, 4G, WLAN .

II. GENERAL ENG THEORY

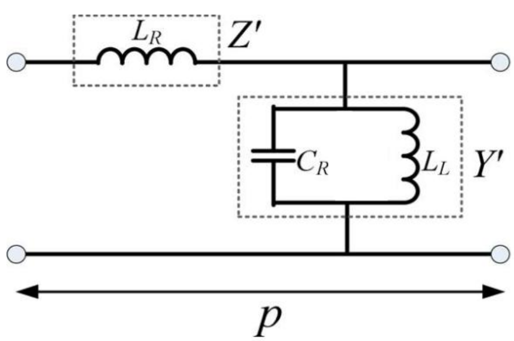

Figure 1 : Circuit Model of an ENG-TL

An equivalent circuit model of an ENG-TL is shown in Fig. 1, which consists of series inductance L_R , shunt capacitance C_R and shunt inductance L_L . The immittances of the ENG-TL are given by

$$Z' = j\omega L_R \quad (1)$$

$$Y' = j(\omega C_R - \frac{1}{\omega L_L}) \quad (2)$$

The same theory is presented in [1] where the extension of bandwidth of both ZOR and FOR antenna takes place.

By applying Bloch and Floquet theory to the unit cell of periodic structures, the dispersion relation is determined by

$$\beta_p = cos^{-1}(1- \frac{\omega^2}{2\omega_R^2} + \frac{\omega_{sh}^2}{2\omega_R^2}) \quad (3)$$

Where,

$$\omega_R = \frac{1}{\sqrt{L_R C_R}} \quad (4)$$

$$\omega_{sh} = \frac{1}{\sqrt{L_L C_R}} \quad (5)$$

β is the propagation constant for Bloch waves, and is the length of the unit cell. The resonance of the ENG-TL for resonance modes can be obtained by the following condition:

$$\beta_{np} = \frac{n\Pi p}{l} = \frac{n\Pi}{N} \quad (6)$$

Where N and l are the number of unit cells and the total physical length of the resonator, respectively. Considering an open-ended boundary condition, the resonant frequency is given by[1],[3],[5]:

$$\omega = \sqrt{\frac{1}{C_R}(\frac{1}{L_L} + \frac{2}{L_R}(1 - cos\frac{n\Pi}{N}))}$$

(where n=0,1,2,….,N-1) (7)

When n is zero, the propagation constant becomes zero and zeroth-order resonance occurs.

$$cos^{-1}(1- \frac{\omega^2}{2\omega_R^2} + \frac{\omega_{sh}^2}{2\omega_R^2}) = 0 \quad (8)$$

$$\omega = \omega_{sh} \quad (9)$$

The resonant frequency of the ZOR is given as

$$\omega = \frac{1}{\sqrt{L_L C_R}} \quad (10)$$

When n=1, first-order resonance occurs and propagation constant is:

$$\beta_p = \Pi \quad (11)$$

Hence,

$$1 - \frac{\omega^2}{2\omega_R^2} + \frac{\omega_{sh}^2}{2\omega_R^2} = -1 \quad (12)$$

$$\frac{\omega^2}{2\omega_R^2} + \frac{\omega_{sh}^2}{2\omega_R^2} = 2 \quad (13)$$

the resonant frequency is given by:

$$\omega = \sqrt{\frac{1}{C_R}(\frac{1}{L_L} + \frac{4}{L_R})} \quad (14)$$

When n is zero, the wavelength becomes infinite and the resonant frequency of the zeroth-order mode becomes independent of the size of the antenna, while the shortest length of the conventional open ended resonator is one half of the wavelength. Thus, an antenna with a more compact size can be realized.

III. ANTENNA DESIGN & SIMULATIONS

According to the ENG-TL theory, the resonant frequencies are only determined by the ENG circuit parameters. In this work, it fully consider the balances of L_R L_L and C_R . Introducing a large L_L and small Cr can extend the bandwidths of the ZOR. Since the gain bandwidth product is constant hence the gain is reduced.

For design and simulation of the antenna, we selected the FR4 substrate with ε = 4.4 and tanδ = 0.02.

Dimensions: L=26mm, W=50mm, W_f = 6.3mm, W_s = 2.6mm , g_1 = 2mm, g_2 = 0.6mm, l_1=1.8mm, l_2 = 4.6mm, l_3= 20.5mm, Ls=16mm, p=5mm, d_1=0.3mm, S_1=0.3mm

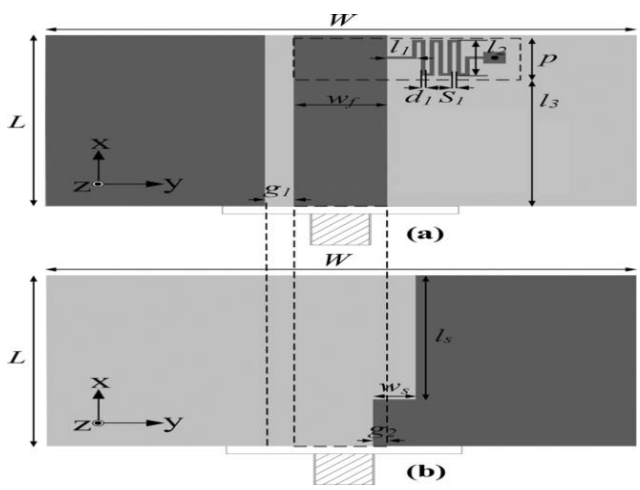

Figure 2: Dimensions of proposed ZOR antenna with vias: (a) Top view (b) Bottom view

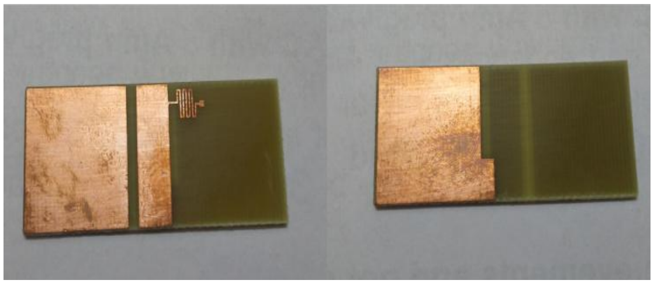

Figure 3 : Top and Bottom view of fabricated ZOR antenna with vias

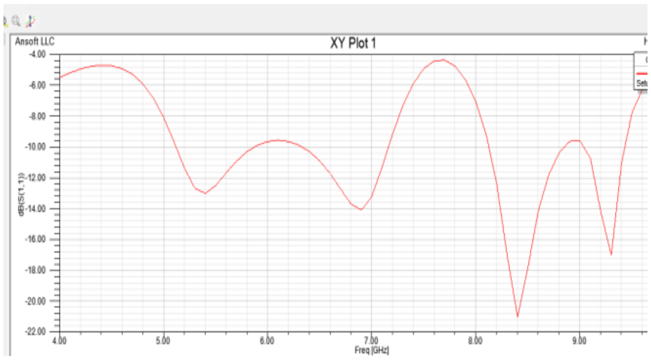

Figure 4: simulated S_{11} graph of proposed ZOR antenna with vias.

At f=5.4Ghz, the radiation efficiency of proposed ZOR anrenna with via is 85.47% with radiated power and accepted power are 810.45 mW and 948.2 mW respectively, where the normalized peak gain and normalized peak directivity are 0.39917 and 0.46702 respectively.

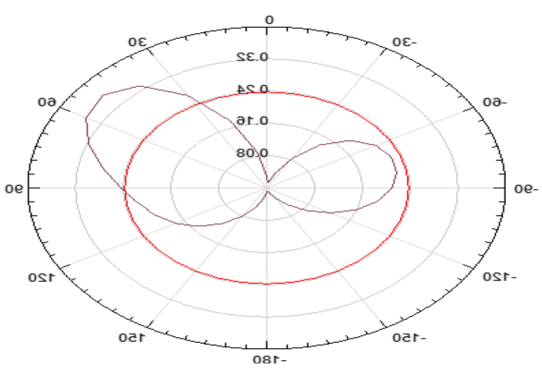

Figure 5: simulated 2-D Radiation Pattern of proposed ZOR antenna with vias at f=5.4GHz

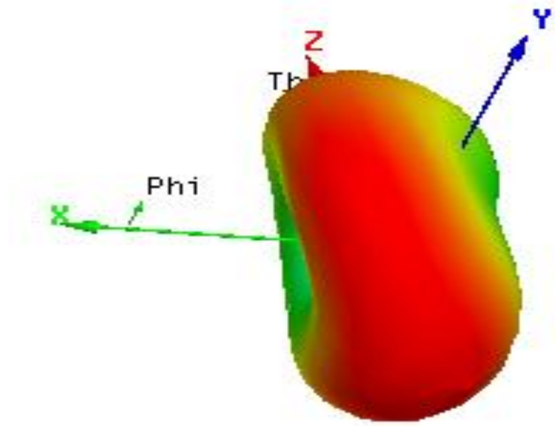

Figure 6: simulated Polar Plot of proposed ZOR antenna with vias at f = 3.2 GHz

The overall size of radiation aperture is 0.46λ x 0.90 λ x 0.028 λ (26mm x 50mm x 1.6 mm) at f=5.4 GHz.

According to [1], the presence of harmonic resonances which interfere the designed ZOR and FOR which is the only drawback of meander lines.

Table 1: Frequency Parameters of Proposed ZOR Antenna with Single Via

PARAMETERS	VALUES
Peak Directivity	0.46702
Peak Gain	0.39917
Peak Realized Gain	0.3785
Radiated Power	0.81045 W
Accepted Power	0.9482 W
Incident Power	0.99998 W
Radiation Efficiency	0.85472
Frequency	5.4Ghz

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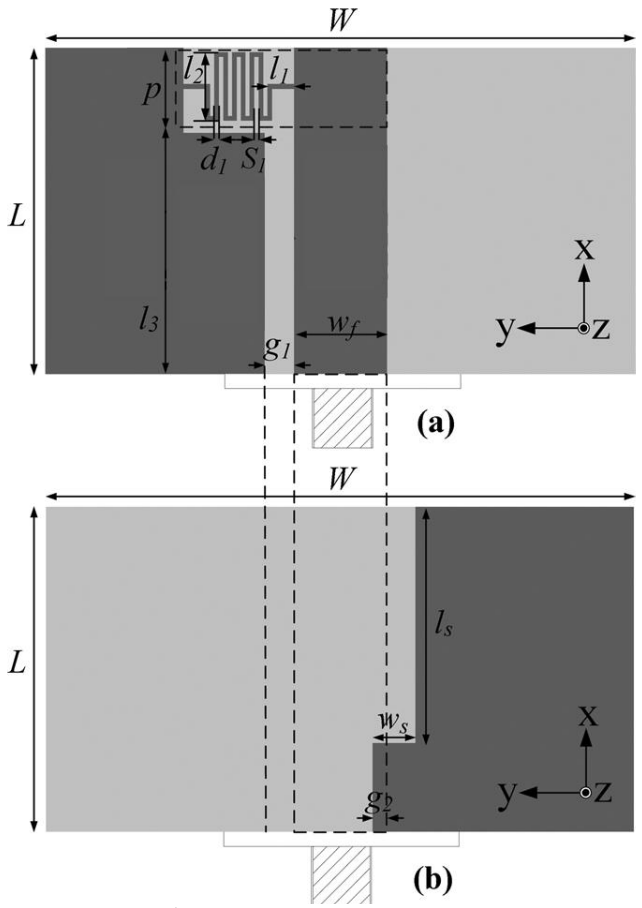

Figure 7:Dimensions of proposed ZOR antenna without vias: (a) Top view , (b) Bottom view

Dimensions: L=26mm, W=50mm, W_f = 6.3mm, W_s = 2.6mm , g_1 = 2mm, g_2 = 0.6mm, l_1=1.8mm, l_2 = 4.6mm, l_3= 20.5mm, Ls=16mm, p=5mm, d_1=0.3mm, S_1=0.3mm

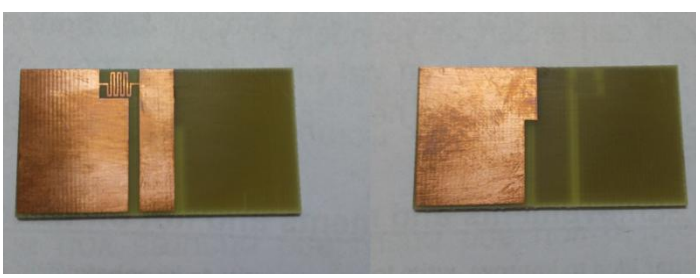

Figure 8: Top and Bottom view of fabricated ZOR vialess antenna

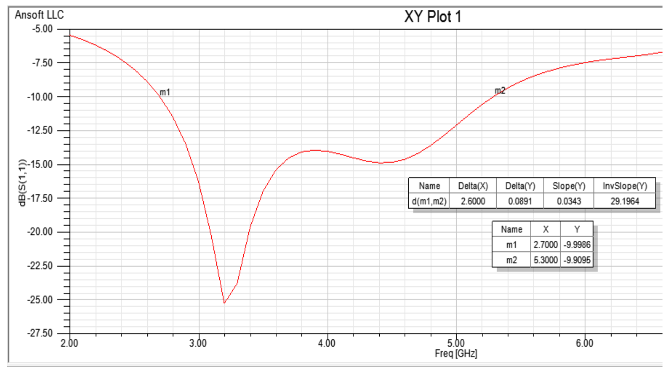

Figure 9: simulated S_{11} graph of proposed ZOR vialess antenna.

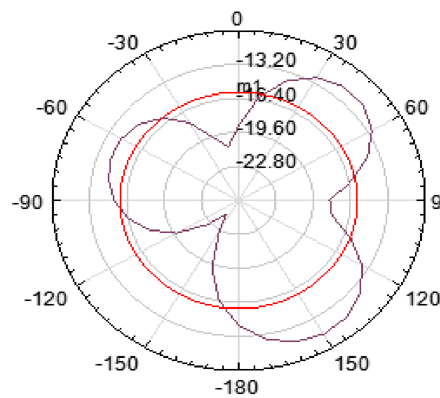

Figure 10: simulated 2-D Radiation Pattern of proposed vialess ZOR antenna at f=3.2GHz

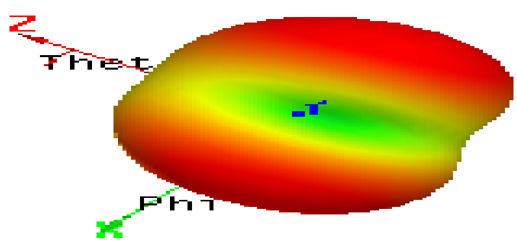

Figure 11: simulated Polar Plot of proposed vialess ZOR antenna at f = 3.2 GHz

Table 2 Frequency Parameters of Proposed Vialess ZOR Antenna

PARAMETERS	VALUES
Peak Directivity	0.076717
Peak Gain	0.071518
Peak Realized Gain	0.071361
Radiated Power	0.93016 W
Accepted Power	0.99779 W
Incident Power	0.99997 W
Radiation Efficiency	0.93222
Frequency	3.2Ghz

The overall size of radiation aperture is 0.27λ x 0.53 λ x 0.017 λ (26mm x 50mm x 1.6 mm) at f=3.2 GHz.

At f=3.2Ghz, the radiation efficiency is 93.22% with radiated power and accepted power are 930.16 mW and 997.79 mW respectively, where the normalized peak gain and normalized peak directivity are 0.071518 and 0.076717 respectively.

ZOR does not depend on the physical size, this makes it is possible to design a smaller resonant antenna than the traditional microstrip resonator antenna. The design without via gives better result than the design with via.

This antenna has a zeroth-order resonant frequency at f_0 = 3.2GHz and radiation efficiency was approximately 93.22%. The proposed antenna is fabricated on a FR4 substrate with a dielectric constant of 4.4 and thickness of 1.6 mm.

IV. CONCLUSION

In this paper, it is demonstrated the bandwidth enhancement of proposed ZOR antenna. The size of proposed antenna can be reduced because of its zeroth order resonance. The circuit model of proposed ZOR antenna was derived and analyzed inorder to study the bandwidth enhancement. The bandwidth is enhanced because of the merging of zeroth order resonance and first order resonance. Here zeroth order resonance makes the antenna compact and first order resonance increases the directivity and gain. Also as the bandwidth increases gain decreases simultaneously. Since the proposed theory and results show good agreement with each other hence the proposed antenna can be used for modern wireless communication system.

V. REFERENCES

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